TITLE: Evaluation of Juvenile *Oncorhynchus Mykiss* Migration and Life History Expression in the Calaveras River using Streamwidth Passive Integrated Transponder Technology

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1. PROJECT PURPOSE

1.1 QUESTIONS OR CRITICAL UNKNOWNS, AND PSP TOPICS AND QUESTIONS

Our Project is designed to address several critical unknowns regarding the influences of anthropogenic and natural factors on juvenile *Oncorhynchus mykiss* (*O. mykiss*) behavior and life history expression in the Calaveras River. For instance, the migration ability and survival rate of juvenile steelhead past numerous anthropogenic structures (e.g., flashboard dams and road crossings) within the lower Calaveras River in relation to environmental and water operations factors is currently unknown. Also, little is known about how environmental factors may influence life-history expression (residency or anadromy) and migration characteristics (e.g., season, time, rate, and migration route) of *O. mykiss* in the Calaveras River, as well as other Central Valley Rivers.

This project will evaluate potential passage impediments and environmental influences on juvenile migration and collect information that will increase "our understanding of population biology, the physical and biological mechanisms underlying population dynamics, and the responses of various life stages of key species to natural and human perturbations" (Attachment 1 in the 2004 Science Program Proposal Solicitation). The information will be used to (1) answer the question, "How do environmental processes and water operations combine to affect the distribution, fate, and population success of at-risk or other native species?" (Priority Topic Area i in the 2004 Science Program Proposal Solicitation) and (2) refine our conceptual model of the factors affecting steelhead in the Calaveras River.

1.2 GOAL(S), OBJECTIVE(S), HYPOTHESES

Our Project goals are to: (1) evaluate numerous potential passage impediments within Mormon Slough and Old Calaveras River Channel to assist in prioritizing structural improvements for salmonid passage and provide baseline information for effectiveness monitoring, (2) identify opportunities for water management flexibility (e.g., flow management between routes) to improve juvenile salmonid passage through the lower Calaveras River, (3) evaluate *O. mykiss* life history characteristics to increase our understanding of factors that influence life history expression and to determine the extent that water management flexibility (e.g. migration route management) may benefit the anadromous component of the population.

Our objectives are to: (1) monitor passage of tagged *O. mykiss* with Passive Integrated Transponder (PIT) tag detection devices throughout potential migration routes between tidewater and New Hogan Dam in the lower Calaveras River, (2) monitor environmental and structural variables throughout potential migration routes between tidewater and New Hogan Dam in the lower Calaveras River, (3) determine the influence of environmental and biological variables on *O. mykiss* migration characteristics and life-history preferences.
Our Null Hypotheses include:

1. Null Hypothesis: Juvenile *O. mykiss* downstream migration is not delayed or impeded at individual irrigation structures and channel irregularities in Mormon Slough and the Old Calaveras River.

   Corollary: If the null hypothesis is rejected, it is highly likely downstream migration is delayed or impeded at individual irrigation structures and channel irregularities in Mormon Slough and the Old Calaveras River. This information will assist in identifying priority areas structural improvements since it is currently unknown which structures and locations are the most limiting. In addition, this baseline information will be used for effectiveness monitoring.

Criteria for rejecting Ho: The null hypothesis will be rejected if migration rate is significantly different ($P<0.05$) between reaches (i.e., above Bellota versus Mormon Slough and above Bellota versus Old Calaveras River).

2. Null Hypothesis: Juvenile *O. mykiss* that are prevented from traveling downstream at Bellota do not migrate back upstream to rear but are entrained or experience mortality in the Bellota pool associated with one or more factors (e.g., predation, disease, temperature, etc.).

   Corollary: If the null hypothesis is rejected, it is highly likely that migrating juveniles blocked at Bellota return to upstream areas where they may residualize (remain in river as trout), or rear for a while and migrate later when passage becomes available at Bellota. This information will allow us to identify potential factors influencing life-history expression (e.g., if migration is prevented for some reason, whether by anthropogenic or natural factors, is anadromous life-history turned off forever or can it be turned on again in subsequent years and by what factors?). Based on this information, we may be able to identify management techniques for turning anadromy "on" or "off" for use in the Calaveras, as well as other rivers. This information could be used to encourage fish to move out during specific times of year when migration conditions are better, or could encourage fish to remain in the river when we know that migration conditions are going to be less than optimal. If the null hypothesis is accepted, we will not be able to ascertain whether fish were entrained or experienced mortality in the Bellota Pool.

   Criteria for rejecting Ho: The null hypothesis will be rejected if we detect fish traveling in an upstream direction past the station(s) above Bellota after the same fish has been detected at Bellota.

3. Null Hypothesis: Juvenile *O. mykiss* downstream migration rate is unaffected by environmental, structural, or biological factors.

   Corollary: If the null hypothesis is rejected, it is highly likely that juvenile *O. mykiss* are able to migrate faster in either the Old Calaveras River Channel or Mormon Slough under certain environmental, structural, or biological conditions. This information, in conjunction with hypotheses 4 and 5, will allow us to ascertain whether water management flexibility (e.g., natural flows diverted into Old Calaveras versus Mormon Slough) is feasible and would benefit fish passage.

   Criteria for rejecting Ho: The null hypothesis will be rejected if a significant difference ($P<0.05$) is found in the median migration rate through one channel or another during a range of times (e.g., one week, one month, one season, etc.). If differences in migration rate are found, we will examine potential relationships of environmental (e.g., flow), structural (e.g., flashboard weirs installed or not installed), or biological (e.g., fish size, age, smolt index, condition factor) conditions with observed migration route.

4. Null Hypothesis: Juvenile *O. mykiss* downstream migration survival is unaffected by environmental, structural, or biological factors.

   Corollary: If the null hypothesis is rejected, it is highly likely that juvenile *O. mykiss* are able to survive better in either the Old Calaveras River Channel or Mormon Slough under certain environmental, structural, or biological factors. This information, in conjunction with hypotheses 3 and 5, will allow us to ascertain whether water management flexibility (e.g., natural flows diverted into Old Calaveras versus Mormon Slough) is feasible and would benefit fish passage.

Criteria for rejecting Ho: The null hypothesis will be rejected if a significantly greater proportion of fish ($P<0.05$) survive through one channel or another during a range of times (e.g., one week, one month, one season, etc.). If differences in survival are found, we will examine potential relationships of environmental (e.g., flow), structural (e.g., flashboard weirs installed or not installed), or biological (e.g., fish size, age, smolt index, condition factor) conditions with observed migration route.

5. Null Hypothesis: Juvenile *O. mykiss* downstream migration routes are unaffected by environmental, structural, or biological factors.

   Corollary: If the null hypothesis is rejected, it is highly likely that juvenile *O. mykiss* migrate more often in either the Old Calaveras River Channel of Mormon Slough under certain environmental, structural, or biological conditions. This information, in conjunction with hypotheses 3-4, will allow us to ascertain whether water management flexibility is feasible and would benefit fish passage.

   Criteria for rejecting Ho: The null hypothesis will be rejected if a significantly greater proportion of fish ($P<0.05$) migrate into one channel or another during a range of times (e.g., one week, one month, one season, etc.). If differences in migration route usage are found, we will examine potential relationships of environmental (e.g. flow), structural (e.g., Bellota Weir installed or not installed), or biological (e.g. fish size, age, smolt index, condition factor) conditions with observed migration route preference.

6. Null Hypothesis: Age 1+ *O. mykiss* migration occurs throughout the year and is independent of seasonal patterns.

   Corollary: If the null hypothesis is rejected, it is highly likely that juvenile migration occurs during specific periods (e.g., seasons).

   Criteria for rejecting Ho: The null hypothesis will be rejected if fish are only detected migrating past stations during specific periods of time.

7. Null Hypothesis: Adults do not return to the river within two years of outmigration.

   Corollary: If the null hypothesis is rejected, it is highly likely that juvenile *O. mykiss* are able to leave the river and spend time in the ocean and/or estuary prior to returning to the river as adults within two years.

   Criteria for rejecting Ho: The null hypothesis will be rejected if a tagged *O. mykiss* released in year one of the study is detected is detected traveling upstream at the lowermost detection station six months to two years after migrating downstream of this lowermost detection station.

2. DESCRIPTION

2.1 BACKGROUND

The Calaveras River extends roughly 60 miles from the Sierra Nevada Mountains to the Stockton metropolitan area, however, anadromous salmonids have been limited to the lower 42 miles of river below New Hogan Dam since 1930 (Figure 1). The lower river between Bellota (RM 24) and New Hogan Dam (RM 42) currently supports a prized rainbow trout fishery, and is opportunistically used by steelhead (Titus 2000; SPC unpublished data) and fall-run Chinook salmon (Yoshiyama et al. 2001) when naturally occurring streamflows for migration into the reach occur.

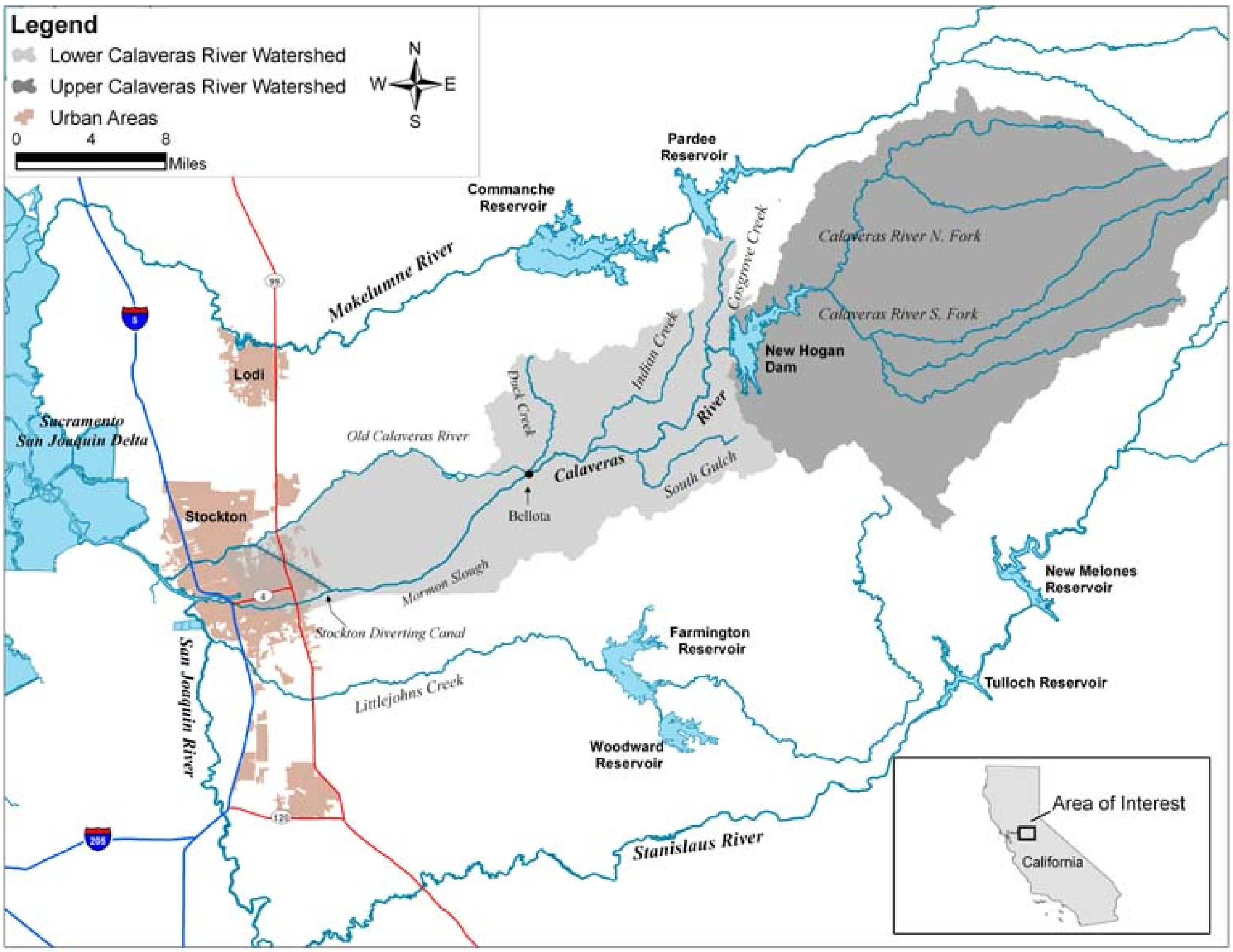

Figure 1. Overview of Calaveras River Watershed.

Below Bellota, the river splits into two channels (Mormon Slough and the Old Calaveras River channel) for roughly 18 miles before rejoining, and then flows for another 6 miles to its confluence with the San Joaquin Delta. In both channels, there are numerous flashboard dams (Reynolds et al.1993; USFWS 1995) which are operated during the irrigation season (April 15-October 15) and other structures (e.g., road crossings; DWR unpublished data), as well as channel morphological features (e.g., wide and highly irregular channel bottom) that result in impaired fish passage under certain flow conditions (Figure 2). Fish passage at individual structures and other potential passage impediments is thought to be either blocked or impeded dependent on several potential factors including, the timing of migration versus flashboard dam configuration (i.e., installed during the irrigation season or un-installed during non-irrigation season) and the magnitude and duration of flows. Yet, the contribution level of influencing factors and magnitude of impairment at individual structures is currently unknown. In addition, the fate of fish that are impeded or blocked from passage is also unknown. For instance, do they return to upstream areas where they may residualize (remain in river as trout), or rear for a while and migrate later when passage becomes available? Do they experience mortality associated with stranding, predation, adverse environmental conditions (e.g., high temperatures)? or do fish that migrate during the irrigation season (April 15-October 15) become entrained into unscreened diversions? This study focuses primarily on downstream passage issues for juvenile steelhead; however, the information that we learn can also be applied to juvenile salmon. In addition, we anticipate that this project will continue for several years past this 3 year grant cycle which will allow us to ultimately collect information regarding passage issues and life-history timing of adult steelhead returning to the river.

Passage downstream of Bellota is typically blocked during the irrigation season (April 15 through October 15) due to numerous flashboard dams installed within Mormon Slough and the Old Calaveras River. However, a small number of juvenile *O. mykiss* have been observed within these areas (FFC unpublished data) indicating that at least some juveniles are able to move past these structures. During the non-irrigation season (October 16- April 14), downstream passage opportunities below Bellota are available during higher flows resulting from flood control releases and/or freshet events but the magnitude and duration of flows resulting in passage is currently unknown.

In 2002-2004, migration studies were conducted at Shelton Road (Figure 2.) during varying periods between December and June using a rotary screw trap (SPC unpublished data). These studies show two different migration

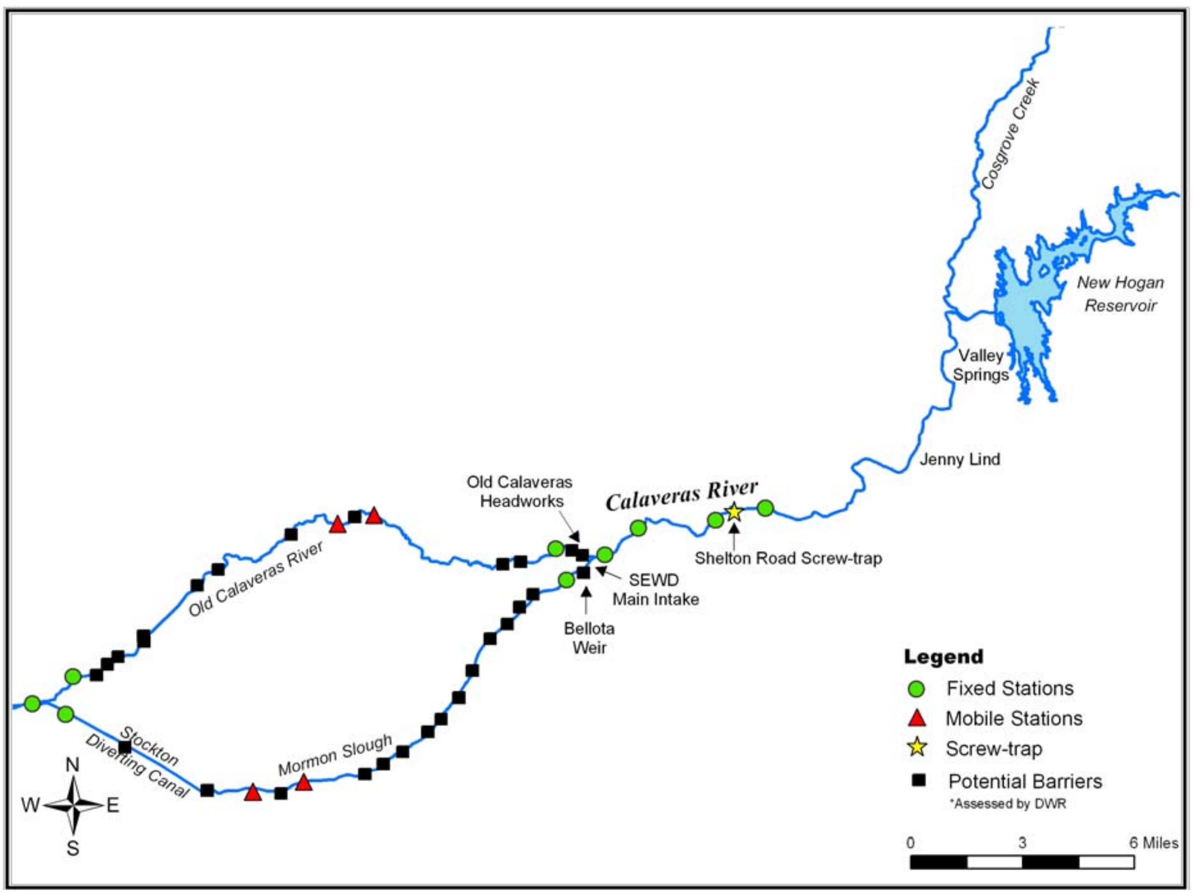

Figure 2. Location of proposed fixed and mobile detection sites, and potential passage barriers in the lower Calaveras River. Potential passage barriers were identified by the Department of Water Resources during a reconnaissance survey. Positions of Mobile Stations are hypothetical in this schematic and would change throughout the study.

patterns for young-of-year (YOY; < 100 mm) and Age 1+ (>100mm) *O. mykiss*. YOY (< 100 mm) *O. mykiss* movement generally occurred in April and May (SPC unpublished data) and coincided with increased flows for irrigation; however, it is unknown whether these fish are “steelhead” trying to migrate to the estuary/ocean, were resident trout actively trying to re-distribute into additional rearing areas, or were resident trout passively displaced due to higher flows. Since a few YOY *O. mykiss* were also observed below Bellota in May during fyke net studies conducted by FFC (FFC unpublished data), there may be a proportion of YOY in the Calaveras River that attempt to emigrate. This migration pattern is also consistent with observations in other watersheds (i.e., Feather and American Rivers) where YOY *O. mykiss* are also captured in rotary screw traps (McEwan 1999; Snider and Titus 1995). On the other hand, Age 1+ juveniles were generally observed migrating from December through March, with some Age 1+ migration observed through June (SPC unpublished data). Many of these Age 1+ juveniles appeared to be steelhead (i.e., *O. mykiss* greater than 100 mm displaying smolting characteristics), therefore, the majority of steelhead smolts appear to migrate during periods when passage opportunities below Bellota become available periodically but their survival rate is currently unknown.

DWR recently conducted a reconnaissance survey of Mormon Slough and the Old Calaveras River and identified numerous potential passage barriers (Figure 2). In 2004, they conducted hydraulic and cross-sectional measurements at about 13 of these structures and are compiling individual models for these structures to help determine whether they meet fish passage criteria established by NOAA Fisheries and CDFG. Although this study provides a thorough inventory of all the potential passage impediments and is a necessary first step for providing estimates regarding the level of flow suspected to provide passage at each barrier, it does not ground-truth the modeling efforts, nor does it address the numerous channel irregularities that can potentially cause stranding. Further, the model has no way of predicting if certain structures cause migration delays (as opposed to complete blockages), and if so, how passage is influenced by flow, fish size, and other variables. Additionally, there is no way to predict how fish choose between the two passage alternatives, and once in a particular channel, how long their migration takes, what their mortality rate is, and what factors influence their success. This Project will build on the DWR study and provide passage and migration data of sufficient resolution to both prioritize future restoration actions and identify water management options that can improve migration opportunities for *O. mykiss*.

In conjunction with DWR’s study, the results of this Project will help identify the extent of migration delays or blockage and the flow conditions necessary for passage at individual structures, as well as identify hydraulic barriers associated with channel morphology, such as a wide and highly irregular channel bottom which leads to development of small pools and isolated channel segments under low flows. Understanding the extent that instream structures inhibit migration, both during the irrigation and non-irrigation seasons, will allow us to refine our conceptual model so that restoration actions (e.g., structural improvements) are focused in areas that are the most important. This Project will also increase our knowledge regarding the potential for migration route management in the lower Calaveras River. For example, the Old Calaveras River channel may be identified as being a better migration route under certain conditions such as during low-level freshet events or during periods when groundwater re-charge can be done effectively in the Old Calaveras. At this time, there are too many unknowns (i.e., the level of flow necessary for passage over individual structures, the duration of flow needed for juveniles to travel all the way to tidewater, and how these factors are influenced by other environmental and biological variables) regarding the usefulness of migration route management to implement this activity. This study would provide answers needed to determine whether migration route management under natural flow conditions is feasible and can increase passage opportunities for *O. mykiss* in the Calaveras River.

2.2 GENERAL PLAN OF WORK

Objective 1. Manage project to ensure that all objectives and reporting requirements are met on time and within budget.

Task 1.1 Project management.

The U.S. Fish and Wildlife Service (USFWS) will be responsible for overall project management and administrative activities. Project management will consist of managing the contract, submitting progress reports, budget tracking and invoicing. The work products will consist of semi-annual fiscal and programmatic reports.

Activity 1.1.1 Execute contract with funding agency and sub-contractors.

USFWS will sign and execute the contract with the funding agency and submit additional information, if required. USFWS will also execute a contract with the sub-contractor, S.P. Cramer & Associates (SPC), and submit a copy to the funding agency within ninety (90) days of execution.

Activity 1.1.2 Provide technical oversight to ensure that all project objectives are met, tasks are carried out in the manner described, and deliverables are completed on schedule.

The USFWS will oversee the implementation of all field activities to ensure that the project objectives are met and that all deliverables are completed on schedule. This includes periodic onsite inspections to ensure QA/QC and coordinating with the field leader to adaptively manage the project in response to unforeseen challenges in the field and modifying sampling elements as needed.

Activity 1.1.3 Manage project funds.

The USFWS will prepare and submit invoices inclusive of subcontractor services to the funding agency on a monthly basis. Three copies of the invoice will be provided to the funding agency, including one signed invoice and two duplicate copies. Activity reports will accompany each monthly invoice and will describe the work conducted during the month.

Activity 1.1.4 Prepare and submit semi-annual fiscal and programmatic reports to funding agency.

The USFWS will prepare and submit fiscal and programmatic reports to the funding agency on a semi-annual basis. The semi-annual reports will describe the fiscal and programmatic status during each six-month period. These reports will include (1) the total amount of money awarded to the project, (2) the amount invoiced to the granting agency, (3) description of activities performed during the six month period and the percentage of each task completed, (4) deliverables produced during the six month period, (5) problems encountered that may delay the progress of the project, and (6) description of amendments or modifications to the grant agreement.

Task 1.2 Prepare and distribute monthly progress reports to various entities.

The USFWS will distribute monthly progress reports via e-mail of all field activities including design and construction, fish collection and tagging, and monitoring results to the agencies, resource managers, and other interested parties. An extensive mailing list of interested individuals has already been generated during past projects and monthly summaries via e-mail were shown to disseminate information to more people and create more response and interest from others, versus paper reports. Monthly progress reports will be prepared by USFWS and SPC and will include a written description of field activities, as well as relevant pictures, tables, and graphs. In addition, an archive of monthly progress reports will be placed on the Calaveras River Fish Group (CRFG) and Calaveras River Watershed Stewardship Group (CRWSG) websites at http://www.delta.dfg.ca.gov/crfg/ and http://www.calaverasriver.com, respectively.

Task 1.3 Prepare and distribute a final comprehensive report to various entities.

USFWS will distribute a final comprehensive written report to resource managers in the Calaveras River and San Joaquin Basin describing events and study findings for the entire Project. The final report will be prepared by USFWS and SPC. In addition, an archive of the final report will be placed on the CRFG and CRWSG websites at http://www.delta.dfg.ca.gov/crfg/ and http://www.calaverasriver.com, respectively.

Task 1.4. Participate in relevant stakeholder groups

The USFWS will participate in relevant stakeholder groups such as the CRFG (members consists of state and federal resource agencies, environmental groups, and other interested parties) to inform interested parties regarding Project progress and solicit feedback. The USFWS will also solicit recommendations from the CRFG regarding the strategic placement of mobile detection stations. Acquiring feedback and recommendations from CRFG members will ensure that the Project is able to address as many areas of interest as possible.

Task 1.5 Participate at workshops, seminars, or conferences.

SPC in collaboration with USFWS will prepare and deliver at least one PowerPoint presentation of study findings and project status to a scientific or resource group (e.g., CALFED, American Fisheries Society, etc.). USFWS and SPC have regularly attended the CALFED Science Conference and American Fisheries Society annual meetings and delivered several presentations at each forum.

Objective 2. Obtain necessary research permits and construct multiple PIT tag detection stations at crucial migration intersects and stream reaches and one roving detection unit.

Task 2.1 Obtain necessary research permits from NOAA Fisheries and CDFG.

The PIT monitoring project will require authorization from CDFG and NOAA Fisheries for collecting, handling, and tagging juvenile *O. mykiss*. All SPC staff in California hold current scientific collecting permits issued by the CDFG. These permits do not authorize any particular sampling activities but are required to conduct research by CDFG. Separate amendments are required for specific sampling activities associated with each individual study conducted. Permit amendments will be obtained from the CDFG Region 2 Senior Fishery Biologist for all proposed sampling activities before field work begins. SPC has conducted the procedures necessary for amendments in the past and are familiar with the requirements and timelines for processing amendment requests. SPC will comply with any and all requirements described by CDFG in permit amendments.

At this time, SPC does not have an incidental take permit (ITP) under Section 10(b) from NOAA Fisheries; however, SPC anticipates receiving an ITP in the near future because the permit process has already been initiated. In 2003, a pilot PIT Tag study for the Calaveras River consisting of a feasibility study and a tentative second year work plan was originally prepared by SPC and submitted to NOAA fisheries with a request for an ITP. The feasibility study consisted of developing and testing detection equipment in the field using dummy fish, conducting laboratory tests of surgical techniques using hatchery fish, and conducting reconnaissance surveys for detection sites. None of these activities required an ITP so these activities were conducted in early 2004 while awaiting authorization to conduct the next year's work plan activities. The work plan was proposed as a limited field study that would be conducted above Bellota whereby the particulars regarding tagging methods and detection station locations would be based upon the results of the feasibility study. Upon public review, reviewer comments indicated that the Project scope should be expanded to encompass the reaches below Bellota in order to get the most beneficial information from the study. Based on reviewer comments and subsequent collaboration with multiple resource agencies (CDFG, NOAA Fisheries, and DWR), the USFWS and SPC have developed a more thorough Project proposal that includes multiple detection stations throughout the river and goals and objectives as recommended by the agencies. The revised joint USFWS and SPC Project will be submitted concurrently to both the CALFED Science PSP and NOAA Fisheries, and the NOAA Fisheries permit process will resume. Since reviewer comments and concerns have been addressed in this joint USFWS and SPC proposal, SPC expects to receive an expeditious ITP authorization.

Task 2.2 Design and construct stationary PIT tag detection stations and roving PIT tag detection units for use in the Calaveras River.

During the feasibility study in 2004, a demonstration detection station was developed according to designs identified by Zydlewski et al. (2003) and tested using a tagged dummy fish. In addition, reconnaissance surveys were conducted to determine appropriate areas for detection stations. Based on results of equipment testing during the feasibility study, reconnaissance surveys, and discussions with resource agencies, we determined that a total of at least 13 stationary detection stations and two roving detection units were needed for a long-term monitoring project (see Tasks 3.2-3.5 for details).

The stationary PIT tag detection stations will be constructed consisting of the same basic electronic components (Appendix A) which were constructed and tested during the feasibility study. Although the basic components of all stationary stations will be the same, there will be two different types of detection stations (fixed and mobile) used during this study. The stations referred to as “fixed” detection stations are those that will remain in the same location for the duration of the study; whereas “mobile” stations will be occasionally moved to evaluate specific passage impediments. For each detection station, antennas will be designed to maximize the detection efficiency for a particular location (Appendix A). Each station will consist of several components that function in unison to detect, identify, and log individual tagged fish as they move past the station. All detection station equipment will be stored in a secured lock box with a concrete base above the bankfull channel level to protect from weathering and vandalism. The antenna will be supported by aircraft cable and enclosed in thick exterior rubber tubing to protect from high flow events or vandalism. Placement of the equipment above the bankfull channel will also eliminate the need for a streambed alteration permits from CDFG and the ACOE.

Two types of roving detection units will also be constructed of the same basic components: a backpack detection system similar in appearance to a backpack electrofisher and a trawl detection system which is boat mounted (Appendix A). Each will be used to actively search for fish between detection stations and will their use is dependent on the habitat type (i.e., shallow, wadeable areas versus deeper more challenging areas)., Roving units will cost effectively expand monitoring area, help locate undetected fish, and allow for microhabitat use assessment (i.e., habitat type and GPS coordinate identified for each detected fish).

Task 2.3 Install and regularly test PIT tag detection stations to demonstrate effectiveness.

Upon installation of individual PIT tag detection stations, the detection range of the antenna will be tested using PIT tags placed in dummy fish to determine that the system is functioning properly, and read ranges are within the expected 5-6 foot read ranges observed during feasibility study testing and documented by other researchers using the same equipment (Castros-Santos et al. 1996; Zydlewski et al. 2003). Antennas will be tuned to detect PIT tags at maximum range by introducing a tag to the outer perimeter of the detection area. As one technician adjusts the antennas tuning, another technician will reintroduce the tag to the detection perimeter. The process will continue until maximum lateral detection range is attained.

For the duration of this study, regular field inspections will be conducted to ensure that station antennas are working properly. The frequency of field inspections will be adjusted based on environmental conditions and field experience. Inspections will include testing the antenna detection range using tagged dummy fish to insure they are always functioning at optimum performance, and determining whether debris needs to be removed or equipment repaired. It is anticipated that field inspections will be conducted more often during freshets and flood control releases when 1) we expect fish to be more actively migrating, and 2) the chance for damage to our antennas by debris or inclement whether is more likely.

Objective 3. Monitor passage of tagged *O. mykiss* with PIT tag detection devices throughout the Calaveras River between New Hogan Dam and tidewater.

A primary concern regarding telemetry is the behavior and physiological response of monitored fish versus their untagged counterparts. Tagged fish must display natural behavior; otherwise, data collected will not adequately represent the population. Many recent studies have documented successful tagging methodologies with negligible effects to fish behavior and physiology (see Feasibility Section under 2.5). During the feasibility study, SPC performed surgical tag insertions using hatchery fish according to these suggested tagging methodologies and identified the benefit of using techniques such as bioadhesive sutures, antibacterial treatments, and reduced handling times, to reduce potential adverse affects to fish. To ensure that tagged fish are representative of natural fish, SPC will apply these tagging techniques during this Project and will monitor post-release tag retention and mortality for a sub-sample of tagged fish.

The tasks and activities described under Tasks 3.2-3.4 are those associated with detecting tagged fish at strategic locations throughout the Calaveras River between New Hogan Dam and tidewater, including Mormon Slough and the Old Calaveras River channels. Stationary monitoring stations will consist of new streamwidth style PIT tag detection equipment previously tested during the feasibility study and described in further detail in Appendix A. Roving stations are also described in Appendix A.

Task 3.1 Annually tag and release fish up to 500 juvenile O. mykiss migrants (>100mm) captured in a rotary screw trap at Shelton Road.

Since 2002, SPC has operated a rotary screw trap at Shelton Road (RM 28; Figure 2) in the Calaveras River during winter and spring, as part of an ongoing juvenile salmonid migration monitoring program for Stockton East Water District. This trap will serve as the primary source of juvenile *O. mykiss* for tagging, since it provides a reliable source of YOY and Age 1+ juveniles displaying smolting and downstream migrating characteristics and it is located at the downstream extent of suitable rearing habitat. The trap is operated intermittently (typically using a 3 days "on" 4 days "off" schedule) so only a portion of the population is sampled.

All fish captured in the trap will be identified and enumerated, while a sub-sample of salmonids (up to 50 from each species each day) will be anesthetized and processed which includes measurements of length (fork length and total length to nearest mm) and weight (to nearest gram); visual assessment for smolt index, ad clips or other marks, and overall health; examination for PIT Tag; and collection of scale samples. After processing, a portion of untagged fish greater than 100 mm will receive a PIT Tag (number of fish receiving tag will be determined through collaborative discussions with USFWS, CDFG, NOAA Fisheries, and SPC). PIT tags will be surgically inserted into fish according to Zydlewski et al. (2003) techniques, but the incision will be closed with a bio-adhesive. During the feasibility study, SPC identified the benefit of reduced surgery times and excellent tag retention with bioadhesive sutures versus silk sutures. Other researchers found that adhesive sutures were up to 35% faster (Petering and Johnson 1991), with silk sutures taking between 2 to 4.5 minutes (Moore et al. 1990, Jepsen et al. 2002). Ombredane et al. (1998) suggested that handling time was a greater factor to overall mortality rates than the presence of the transmitter itself.

Fish will only be tagged at temperatures up to 16°C. After tagging, fish will be placed in freshwater and allowed to recover a minimum of 0.5 hours before release below the trap and periodically a sub-sample of fish will be held in live cages for up to 24 hours to measure delayed mortality and tag loss. Exact protocols for releasing fish and for post-release tests will be determined and may be modified during the study through collaborative discussions with resource agencies.

Task 3.2 Monitor migration routes and timing of tagged O. mykiss within the river below Bellota using PIT tag detection stations in the Old Calaveras River and Mormon Slough.

Juvenile salmonids migrating downstream below Bellota have two possible migration routes to choose from including Mormon Slough or the Old Calaveras River. Route choice may be influenced by the magnitude or proportion of flow entering each channel, particularly during high flow events when a majority of flows travel through Mormon Slough; however, at lower flows which occur frequently during the outmigration period this may not be the case. Both routes are approximately the same length but each has unique characteristics that pose potential benefits or drawbacks for migrating juveniles dependent on a variety of factors such as season of use, level of flows in each channel resulting from controlled reservoir releases and/or freshet events, diversion rates at Bellota (head of Mormon Slough) and the Old Calaveras River Headworks (Headworks), seasonal configuration and operation of multiple irrigation structures in each channel (e.g., Bellota Diversion Dam, unnamed flashboard dam structures and unscreened diversions); and harassment hotspots located in urban area sections. Information obtained from this portion of the study will allow us to analyze the potential benefits gained by implementing management flexibility (e.g., migration route management).

During the feasibility study, we determined that a total of five fixed stations should be located between Bellota (RM 24) and tidewater to continuously (24 hours/day, 7 days/week) monitor fish passage at critical migration route intersects (i.e., Bellota Weir, Old Calaveras River Headworks, and the lower ends of each channel) for the duration of the study. The Bellota Weir consists of an upper flashboard dam (6 foot high during the irrigation season and 2 foot during the non-irrigation season) and a lower concrete apron with an approximately 6 foot drop. Two fish ladders are installed, one at the upper and one at the lower portion of the structure, during the non-irrigation season (October 15-April 14) to assist fish passage. The Old Calaveras Headworks consist of a slidegate structure that is opened and closed manually in order to divert water into the Old Calaveras River during the irrigation season and during portions of the non-irrigation season for groundwater re-charge. Fixed station monitoring stations will be placed at the top and bottom of each route, and below the downstream confluence near tidewater (Figure 2).

Since the detection stations will be operated continuously, tagged fish can be detected whenever water is flowing into the channels and fish have the opportunity to move downstream. As fish move over the Bellota weir and into Mormon Slough, or through the Headworks and into the Old Calaveras River, they will be detected by the first monitoring station in each channel, and the date, time, and unique tag code will be recorded. As fish migrate downstream in either channel, they have the opportunity to be detected and recorded at multiple sites, including at two mobile stations (see Task 4.2) near instream passage impediments, one station at the downstream end of each channel, and one station below the confluence of each channel.

Data will generally be downloaded bi-weekly but download frequency may increase or decrease dependent on field conditions and/or magnitude of fish movements observed. The migration rate of each fish will be obtained by comparing the date and time of detections at various stations. The number of stations throughout the river and migration corridors will allow us to evaluate migration rate on a broad geographic scale, as well as at the reach scale. Some fish may exhibit slow or inconsistent migration rates, which will be individually evaluated to determine if it is the result of passage impediments and/or environmental conditions. Instream survival will be documented as fish pass the lowermost detection station. Fish that disappear between detection stations will be actively searched for with a roving detection unit, which will allow for more precise determinations of the fate of each tagged fish (see Task 3.5).

Although detection rates for individual antennae may vary depending on antennae type (i.e. pass-over or pass-through), location, and environmental conditions, we expect detection rates to be high and the majority of fish to be detected based on feasibility study results and experiences of other researchers. For instance, we achieved 100% detection of dummy tags at an antenna in water as deep as five feet during feasibility testing. While, other researchers using the same technology (both tags and monitoring components) have demonstrated individual antenna detection rates between 72% and 97% (McCutcheon et al. 1994; Zydlewski et al. 2001) and overall seasonal detection rates (i.e., the additive combination of individual detection rates for fish detected at multiple stations) as high as 100% (Gayle Zydlewski, personal communication).As determined in previous studies, multiple detection stations increase the ability to detect individual fish at some point along their migration route. Due to the number of detection stations that will be located throughout the Calaveras River for this study, a few missed tag detections will not limit the interpretations of our results or our ability to accomplish our objectives.

Task 3.3 Monitor the ability of tagged O. mykiss to migrate past suspected passage impediments in the Old Calaveras River and Mormon Slough.

There are numerous potential passage impediments in both Mormon Slough and the Old Calaveras River. Although DWR is conducting hydraulic analyses at several of these structures to identify passage problems and recommend improvements, a fish migration monitoring study will assist in prioritizing structural improvements, provide baseline and post-construction information for effectiveness monitoring, and help determine whether migration route management is feasible. Effectiveness monitoring will not only be useful for determining whether structural improvements have increased fish passage success in the Calaveras River, but can also be used to validate assumptions that are inherent in the hydraulic modeling analyses that are currently used for fish passage evaluation. In addition to structural passage impediments, there is a relatively large unscreened diversion at Bellota that may result in impaired passage. At this time, a permanent screening solution is being designed for this facility and a temporary screening solution is being explored. Although there may be physical limitations for placing an antenna at the structure, the feasibility of this option will be explored as part of effectiveness monitoring for the screen.

During the feasibility study, we determined that four mobile stations should be used to assess specific impediments or channel irregularities in Mormon Slough and the Old Calaveras River channels, and can potentially be used to evaluate fish screen effectiveness at the Bellota Diversion. In addition, these stations are necessary to increase the opportunity for each tagged fish to be detected multiple times during its migration which will ensure that we have sufficient data for analyses (see Task 4.1). Mobile stations may be used singularly or in pairs (i.e., one placed immediately above and one placed immediately below a barrier) at potential passage barriers or Bellota diversion and will be periodically relocated to monitor individual structures in each channel at different flows. The original and subsequent placement of these stations, as well as the duration of operation at each location, will be determined in consultation with DWR, and members of the CRFG.

Data will generally be downloaded bi-weekly but download frequency may increase or decrease dependent on field conditions and/or magnitude of fish movements observed. The migration success of tagged fish past targeted structure(s) will be obtained by comparing the date and time of detections above and below the targeted structures. Results will be compared to environmental conditions to examine relationships between passage/non-passage of individual fish with environmental conditions. Active monitoring using a roving detection unit will be used periodically after freshet events to determine whether fish that are not detected at stations below targeted structures are stranded in areas above the structures (see task 4.4).

Task 3.4 Monitor migration timing of tagged O. mykiss within the river above Bellota using fixed monitoring stations between Bellota and New Hogan Dam.

Several *O. mykiss* life histories may be present in the river above Bellota where spawning and rearing occur, including (1) fish that remain close to their natal area throughout their life, (2) fish that migrate substantial distances up and down within the river to find advantageous habitat in freshwater, and (3) fish that migrate to the ocean and then return to spawn. All three life histories may occur concurrently or at different times and life-history expression may be influenced by natural or anthropogenic factors.

During the feasibility study, we determined that four fixed detection stations are needed in the Calaveras River above Bellota (Figure 2) to evaluate in-river migration characteristics and life-history expression and the downstream movement of fish as they near the two lower migration routes (i.e., Mormon Slough and the Old Calaveras River). Monitoring fish above Bellota will enable us to determine the fate of downstream migrating fish that are prevented from traveling past Bellota during certain times of the year, including whether they (1) migrate back upstream to rear where they may residualize (remain in river as trout), or rear for a while and migrate later when passage becomes available at Bellota, or (2) are entrained or experience mortality in the Bellota pool associated with one or more factors (e.g., predation, disease, temperature, etc.).

Two monitoring stations will be located near Bellota, including one at the Bellota Diversion Dam and another approximately ¼ mile upstream from the Bellota Diversion. This will allow for detailed evaluation of fish movement in this reach, including the extent fish utilize this area or return upstream to rear when water is not flowing over Bellota and downstream passage is blocked.

Two monitoring stations will be constructed near Shelton Road, one about ½ mile downstream from the rotary screw trap just below where tagged fish will be released, and another about ¼ mile upstream of the trap. This "bracketing" of the trap and release site will provide finer resolution of fish movement upon release which will allow evaluation of fish behavior post-tagging including the ability to answer questions such as: Do fish migrate immediately downstream after tagging or are they delayed? And, do fish migrate back upstream of the trap? The Shelton Road reach break also approximates the downstream extent of rearing habitat for *O. mykiss* which will allow us to evaluate potential seasonal and temporal movement patterns of juveniles.

Task 3.5 Use roving detection units to survey areas between detection stations to evaluate non-migratory or stranded fish.

At times, we anticipate that tagged fish may not migrate past detection stations for a variety of reasons (parr not ready to migrate yet, blocked at a structure, stranded in isolated pools, etc.) so we need an additional detection method that can be used to examine habitat utilization by non-migratory fish in upper rearing reaches and in potential stranding areas within Mormon Slough and the Old Calaveras River. Two roving detection units (one backpack unit and one boated mounted unit) will be used periodically to search specific areas between detection stations, such as pools upstream of flashboard dams or in suspected rearing reaches. The frequency and location of these surveys will be determined from the passage data collected from upstream and downstream detection stations. Because each tagged fish carries a unique code, we will know if individual fish do not pass a particular monitoring station and we can use the roving detection unit to determine whether a fish may be rearing, stranded, dead, or otherwise shed its tag. Mortalities will be distinguished from rearing fish by the lack of movement between detections, either during a particular survey or between surveys. Snorkel or SCUBA may be used to confirm the fate of tagged fish displaying no or abnormal movement. Abnormal movement may result if tagged fish are eaten by larger predators, with the tag remaining in the digestive system of the predator. During active searches, GPS coordinates will be taken at the beginning and end points of the surveyed reach and at each fish detection location. Habitat type will be noted wherever fish are detected. Fish detections will be mapped relative to habitat type.

Roving units will provide us with more information that will collectively improve our ability to evaluate a suite of environmental and biological data to more effectively determine the factors that influence successful migration. For instance, we will be able to confirm habitat usage of detected fish and confirm whether fish are stranded in isolated pools. We will also be able to identify whether fish that hold in rearing reaches above Bellota or are stranded in isolated pools eventually migrate under additional flow events.

Objective 4. Monitor environmental and structural variables in the Calaveras River between New Hogan Dam and tidewater.

Data regarding environmental and structural variables will be collected to examine potential relationships with fish passage. All environmental variables and status of structural configurations will be inputted into a SEWD Operations database and updated regularly. The database will be posted at a password protected link at http://www.calaverasriver.com.

Task 4.1 Compile information regarding environmental and structural variables in the Calaveras River between New Hogan Dam and tidewater.

Environmental measurements will include flow, water temperature, turbidity, precipitation, and diel period. There are two remote flow gaging stations operated by the ACOE in the lower Calaveras River: (1) New Hogan Dam and (2) Escalon-Bellota located in Mormon Slough just below the Bellota Weir (Figure 3). In addition, an unnamed gage operated by SEWD will be located at the juncture of Stockton Diverting Canal and Mormon Slough. Daily flow data from these gages will be obtained from the Army Corps of Engineers' (ACOE) water operation website and from SEWD's recording station. Water temperature will be recorded hourly year-round using six HOBO® data logger located throughout the river (Figure 3). Instantaneous turbidity will be collected onsite by field staff during capture and release events, field inspections and station downloads. Daily precipitation for the basin will be obtained from the ACOE's water operation website. Diel information will be obtained from the time stamp generated as individual fish migrate past PIT tag detection stations.

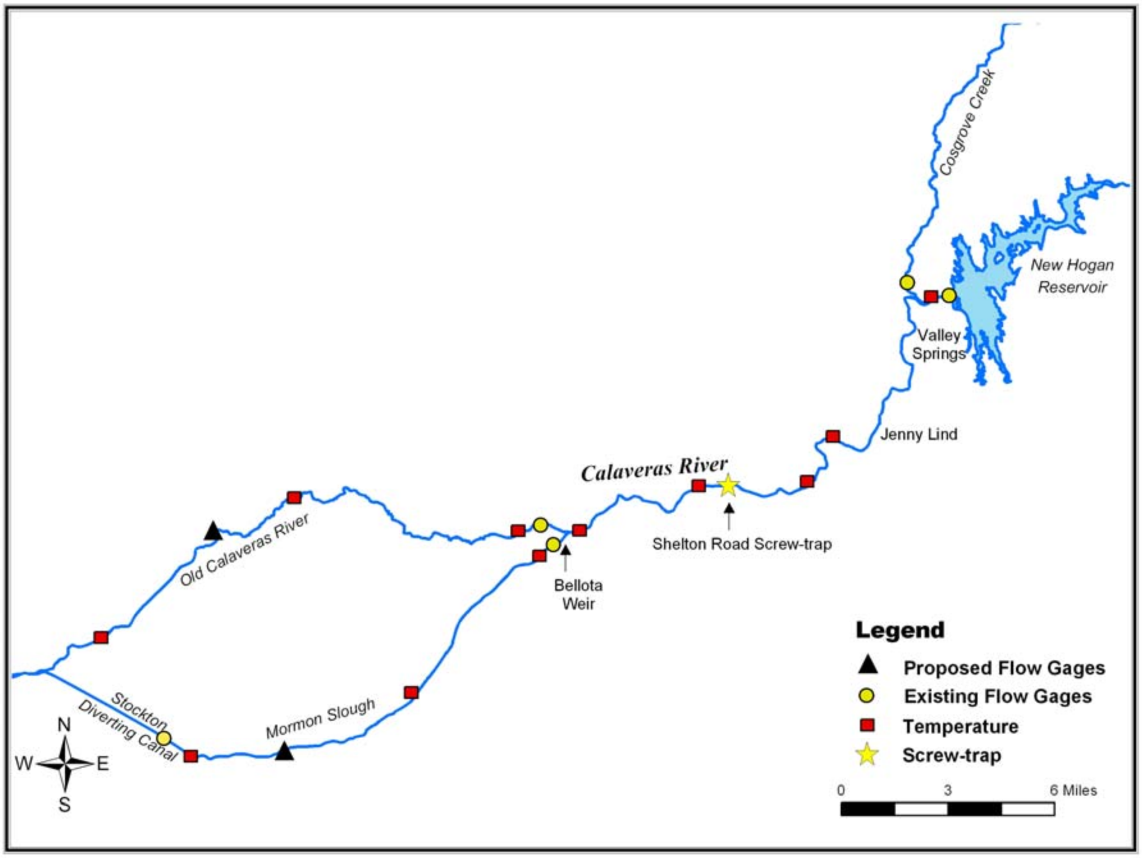

Figure 3. Location of existing and proposed flow gages, existing thermographs, and rotary screw trap site in the lower Calaveras River watershed.

Status of structural configurations will include dates of installation, removal, and operation of various instream structures that may affect fish passage. SEWD currently installs flashboards at numerous structures within Mormon Slough (including Bellota Weir) and the Old Calaveras River at the beginning of April and these structures remain in place through mid-October. Once all flashboards are removed, a temporary 2-foot dam is installed at the Bellota Weir along with two temporary denil fish ladders. The upper ladder is periodically opened and closed dependent on flow conditions and the potential for upstream migration. As part of SEWD's Operations database, SEWD will note the date of installation and removal of the flashboard dams within Mormon Slough and Old Calaveras River, installation and removal of the 2-foot dam and associated fish ladders at Bellota, and the operation of the ladder (open or closed).

Task 4.2 Install and operate new stream gages at two locations.

Currently, there are only three flow gages in the lower river (one at New Hogan Dam, and one each at the upper ends of Mormon Slough and the Old Calaveras River) and one anticipated to be installed near the juncture of Mormon Slough and Stockton Diverting Canal. In addition, there is one gage located in a tributary known as Cosgrove Creek (Figure 3). Due to diversions and tributary inputs below the upper Mormon Slough and Old Calaveras River gages, daily flow data at these gages often does not reflect the flow changes that can occur in both of these channels. For example, there are many times in the lower river when flow ceases (i.e., no connectivity from Bellota to San Joaquin River) but there is flow recorded at Mormon Slough. Monitoring water losses associated with irrigation between spring and fall and gains associated with tributary inputs during the winter and spring in these areas will provide a better assessment of what water is available for fish passage at all times of the year in the lower river.

New gaging stations are needed in the lower river to accurately assess flow characteristics which will be compared with fish passage detections.

Non-submersible pressure transducers (i.e., bubbler gage) are a cost efficient method for remote monitoring of flow conditions. The transducer flow-gage consists of a pressure-sensitive diaphragm system with a gas-purge system which converts the pressure forces of water (i.e., pressure exerted by water at any point in the water column is a function of water depth) to electrical signals that are sent to a remote display and datalogger.

Based on recommendations from DWR, two new flow gages will be installed and operated, one within the lower end of the Old Calaveras River and one within Mormon Slough (Figure 3). The gage within the lower Old Calaveras River will measure channel losses and gains which may fluctuate widely. The gage in Mormon slough will be placed upstream of where Potter Creek drains into Mormon Slough to measure channel losses from between Potter Creek and Bellota which can be considerable according to DWR.

Objective 5. Determine the influence of environmental, structural, and biological factors on migration characteristics and life-history preferences.

Task 5.1 Examine relationship of salmonid passage timing, location, size/age distribution (at release) with environmental, structural, and biological factors

Data pertaining to number and size/age (at release) of salmonids along with environmental parameters will be summarized in charts, graphs, and tables. Depending on the form of the hypothesis and distributional properties of the data, an appropriate statistical test will be applied to determine potential relationships or correlations between environmental (e.g., flow, temperature, turbidity), structural (flashboards installed or not installed, particularly at Bellota), and biological (e.g., size/age at release, estimated size at detection based on growth curves) parameters and migration activity. The suite of likely candidate tests includes least squares regression, Student's *t*-test, Kolmogorov-Smirnov test, ANOVA, and the chi-squared test. The preliminary suite of potential analyses will be expanded as needed. Analyses will be discussed in the final comprehensive report.

Task 5.2 Refine conceptual model

According to the Strategic Plan for Ecosystem Restoration Program (CALFED 1998),

> Conceptual models are based on concepts that can and should change as monitoring, research, and adaptive probing provide new knowledge about the ecosystem. When key concepts change, the conceptual models should be updated to reflect these changes, thereby paving the way toward changes in management.

Our conceptual model (Figure 4) is currently based on the limited data that has been collected primarily over the last few years by SPC and FFC regarding *O. mykiss* populations within the Calaveras River. This study is designed to provide new information that can be used by resource managers who make decisions on the management and protection of steelhead in the Calaveras River. Secondarily, this new information will allow us to update and revise our conceptual model as our knowledge of migration timing and influencing factors increases.

Details will be added to the conceptual model based on the answers to questions including, but not limited to: What is the level of influence that various factors (e.g., flow, structural configuration, water temperature, etc) have on juvenile migration? Is one migration route better than another under some conditions? Do juveniles prevented from migrating by anthropogenic or natural causes wait to migrate at another time or do they residualize? The refined model will "strike a balance between incorporating enough detail to capture the necessary ecological structure and processes and being simple enough to be useful" for helping to identify priority restoration actions and areas of potential management flexibility (Leland et al. 2000). Refinements to the model will be made with collaborative assistance from members of the CRFG.

2.3 PRODUCTS

Products of the proposed Project will include monthly progress reports (Task 1.2), semi-annual fiscal and programmatic reports (Activity 1.1.4), comprehensive annual reports (Task 1.3), and presentations at workshops, seminars, and conferences (Task 1.5).

Expected benefits from the Project include (1) information obtained that can be used in conjunction with DWR study results to prioritize passage improvement projects and (2) greater understanding of the environmental influences on *O. mykiss* life history characteristics in the Calaveras River, as well as other Central Valley rivers and streams. The former will result in identification and ultimately implementation of the most appropriate and feasible passage improvement projects that will allow more fish to emigrate successfully, as well as secondarily allow adults to immigrate more successfully. Increased emigration success is expected to lead to increased escapement, which will help attain the salmon and steelhead doubling goals of the AFRP and help in the recovery of federally threatened Central Valley steelhead. The latter can be used as a baseline comparison for evaluating the success of future structural improvements and other restoration actions within the Calaveras River. In addition, this latter information will be used to determine whether there are certain flow conditions whereby flexible operation of facilities in the Old Calaveras River and Mormon Slough channels results in improved passage conditions for juvenile migrants. Also, lessons learned in the Calaveras River could be used to extrapolate to other watersheds where detailed data is unavailable. For instance, we may be able to identify management techniques that influence anadromy for use in the Calaveras, as well as in other rivers (i.e., techniques to encourage fish to move out during specific times of year when migration conditions are better, or conversely, encourage fish to remain in the river when we know that migration conditions are going to be less than optimal).

2.4 DISSEMINATION OF RESULTS

The USFWS and SPC will collaboratively prepare and USFWS will distribute monthly progress and comprehensive annual reports to various entities including "the scientific research community, the technical community within California Bay-Delta Authority agencies and core stakeholder organizations, and the broader public interested in water and environmental issues" (Task 1.2 and 1.3). USFWS and SPC will also participate in relevant stakeholder groups (Task 1.4) and at workshops, seminars, and conferences (Task 1.5) to share Project information. See tasks 1.2 to 1.5 for details.

2.5 FEASIBILITY AND APPROPRIATENESS OF ACTIVITIES

Several issues that could affect the ability to accomplish this Project include, the ability to tag and detect fish successfully, timeframe (i.e., three years) adequate for collecting sufficient data, and timely receipt of permits. The following indicates that we will be able to complete the project within the three year contract period. Based on three years of sampling with a rotary screw trap at Shelton Road, we will be able to collect enough fish to tag for this Project (see Task 3.1). Although there are concerns that tagging may adversely affect fish behavior and survival, several studies have investigated the affects of surgically inserting tags similar in size to this Project into *O. mykiss* and Chinook salmon ranging in size from 87mm to 180mm+ and found negligible affects from transmitter attachment. For instance, no significant changes in behavior (Brown et al. 1999), survival (Zydlewski et al. 2003), stress (Jepsen et al. 2001), predator avoidance (Anglea et al. 2004), swimming performance (Brown et al.1999; Anglea 2004), feeding or growth (Martinelli et al. 1998), and buoyancy (Perry et al. 2001) were observed.

In 2004, SPC tested equipment and surgical procedures in the Calaveras River and a laboratory setting, respectively. Results of equipment testing during the feasibility study and findings from other researchers (McCutcheon et al. 1994; Zydlewski et al. 2001) indicate that instream detection stations can remotely monitor tagged *O. mykiss* with sufficient detection efficiencies ranging between 72% and 100% for individual antennae and overall seasonal detection rates up to 100% (Gayle Zydlewski, personal communication). Surgical procedure evaluations indicate that *O. mykiss* can be efficiently tagged. Reconnaissance habitat surveys indicate that appropriate areas can be selected based upon required physical and geomorphic criteria. These areas are located within SEWD service areas so access is available. Initial safeguards include the use of multiple stations that are continuously monitoring (24 hours per day) which will increase potential detection ability and protect against equipment failure, and the use of technicians that are trained in state-of-the-art surgical procedures to minimize handling effects. As the Project proceeds, additional safeguards may be implemented based on collaborative discussions with resource agencies and members of CRFG.

Although this Project is only for three years which limits the analyses that can be done on the data collected, it is expected that this Project will provide the mechanism and wherewithal for initiating a multi-year study. Due to the availability of detection station equipment resulting from this Project, it is anticipated that PIT Tag monitoring will be extended for several years as part of an ongoing fishery monitoring program being conducted by Stockton East Water District. The level of monitoring in subsequent years may be increased or decreased dependent on results of the Project, recommendations from the CRFG, and funding availability. This Project will provide necessary baseline information regarding juvenile migration characteristics and potential influencing factors which will be preliminarily analyzed. In subsequent years, additional information pertaining to juveniles collected through the potential extension of the PIT tag program would provide a more robust dataset for analyses. In addition, a long-term PIT tag monitoring program would be able to collect information pertaining to returning adults (e.g., migration timing, age at return) which can be used to determine smolt to adult survival.

Detection equipment will be installed above the highwater mark and only antennae wire will be instream (either flat on substrate or attached to existing structures, so no streambed alteration permits from CDFG or the ACOE will be required. Research permits to capture and handle fish will be required from CDFG and NOAA Fisheries (see Task 2.1 for details).

3. JUSTIFICATION

This proposed Project addresses several CALFED priority topics identified under Section 1, and AFRP concerns in the Calaveras River (e.g., fish passage). This proposed work is consistent with the monitoring needs for Central Valley steelhead identified in CMARP including the need to conduct comprehensive monitoring (document occurrence, assess smolt production, and provide indices of abundance); life stage determination; evaluate migration and rearing flows and microhabitat usage below dams in tailwater reaches; and life-history characteristics (location and timing of rearing, immigration and emigration timing, size/age at emigration, etc.).

3.1 JUSTIFICATION RELATIVE TO EXISTING KNOWLEDGE

The life history of (*Oncorhynchus mykiss*) is complex, and both resident (i.e., rainbow trout) and migratory (i.e., steelhead) strategies may be found within the same watershed (Shapovalov and Taft 1954; Zimmerman and Reeves 2000). Resident rainbow trout complete their entire life cycle in freshwater, while steelhead reside in freshwater for one to three years before migrating to the ocean. In the Central Valley, it is believed that most steelhead migrate to the ocean after spending two years in freshwater (Hallock et al. 1961, Hallock 1989). It is currently unknown what stimulates anadromy versus residency. However, the development of a polymorphic population structure whereby anadromous and stream-dwelling rainbow trout are able to interbreed has been theorized as a response to an environment that is frequently suboptimal and not conducive to consistent, annual recruitment of migrants to the ocean, and may be necessary for long-term persistence of a population in these types of environments (Northcote 1997; Jonsson 1985, as cited in Northcote 1997; Titus and Mosegaard 1992). At present, the limited knowledge regarding *O. mykiss* life history characteristics and how "environmental processes and water operations combine to affect the distribution, fate, and population success" of steelhead hampers the ability to effectively manage their populations in Central Valley streams and rivers including the Calaveras River.

Currently, little data has been collected regarding the abundance, life-history preferences, and migration success of *O. mykiss* in the Calaveras River which makes it difficult to ascertain potential impacts on rainbow/steelhead trout resulting from various human activities and from the recently discovered introduction of New Zealand mud snail into the area. Additionally, the lack of information on migration characteristics (e.g., season, time, rate, and route), make it difficult to evaluate potential passage impediments in Mormon Slough and the Old Calaveras River. Upstream migration to spawning habitat for adults and downstream migration to the ocean for juveniles is fundamental to the survival of anadromous species such as steelhead and Chinook salmon. Therefore, evaluation and subsequent improvement of substantial passage impediments in Mormon Slough and the Old Calaveras River is necessary to minimize take of federally threatened steelhead and facilitate population recovery within the San Joaquin Basin.

Since 2002, a salmonid migration monitoring program aimed at providing juvenile emigration indices (using a rotary screw trap) has been conducted to document baseline data regarding juvenile salmonid presence, abundance, and migration behavior, as well as identify the environmental and/or water management conditions that effect juvenile salmonids ability to migrate successfully out of the river and susceptibility to entrainment into unscreened diversions. Based on results of this study, it has become evident that additional information is necessary regarding *O. mykiss* migration patterns that can only be collected using a different monitoring technique. Rotary screw traps can provide gross measures of migration characteristics (e.g., daily numbers, size at capture, timing), and their ability to detect fish is influenced by flow levels (e.g., trap can be washed out at high flow levels). Another sampling method is needed that can provide a finer-scale of resolution of migration characteristics under varying flow conditions including the ability to answer questions such as: How fast do fish travel under varying flow conditions? Do juvenile fish encountering a downstream passage barrier return upstream and wait until higher flows provide better downstream passage opportunities? What are instream survival rates, as well as smolt to adult survival rates? What influences migration route preferences below Bellota and what passage impediments pose threats and under what conditions? How does flow influence migration and habitat preferences?"

The Calaveras River is an appropriate location for this type of research because 1) it has a known healthy trout population with a substantial proportion displaying anadromous tendencies, 2) the population has had little or no hatchery influence from domesticated strains of *O. mykiss*, 3) the basin contains excellent trout habitat and is of a physical size, has appropriate access, and a flow regime suitable for this type of evaluation, and 4) it virtually becomes a closed system during certain times of the year when flow ceases to occur below Bellota, and therefore provides a unique opportunity to evaluate behavioral responses to migration challenges. The unique characteristics of this basin provide an opportunity to improve our understanding of *O. mykiss* life history characteristics that may have management implications throughout the entire Central Valley. For instance, continuous monitoring of upstream and downstream migrants at multiple locations will for the first time allow researchers to observe behavioral responses that may lead to changes in *O. mykiss* population distribution and abundance. Together with environmental data this will enable us to evaluate the influence of environmental factors and help create effective life cycle models that separate natural variability from anthropogenic forces, and ultimately provide the necessary information concerning management assumptions for this species throughout the Central Valley.

3.2 CONCEPTUAL MODEL

Based on our current understanding of steelhead life-cycle (McEwan and Jackson 1996; Busby et al. 1996, CALFED 1999; NOAA Fisheries 1996) and of potential stressors for various stages in the Calaveras River (CALFED 2000; AFRP 2001), we have developed a preliminary conceptual model that presents potential stressors for steelhead smolt outmigration (Figure 4). Our conceptual model indicates that passage barriers are considered to be one of the primary limiting factors for steelhead. At this time, our conceptual model is limited due to lack of existing information regarding fish populations in the basin. Our Project is designed to evaluate passage barriers and to increase understanding of steelhead life-history within the Calaveras River improving the resolution of our conceptual model so that appropriate restoration actions such as structural passage improvements can be properly prioritized. Also, opportunities to influence migration routes though flexible water management will be identified for future implementation.

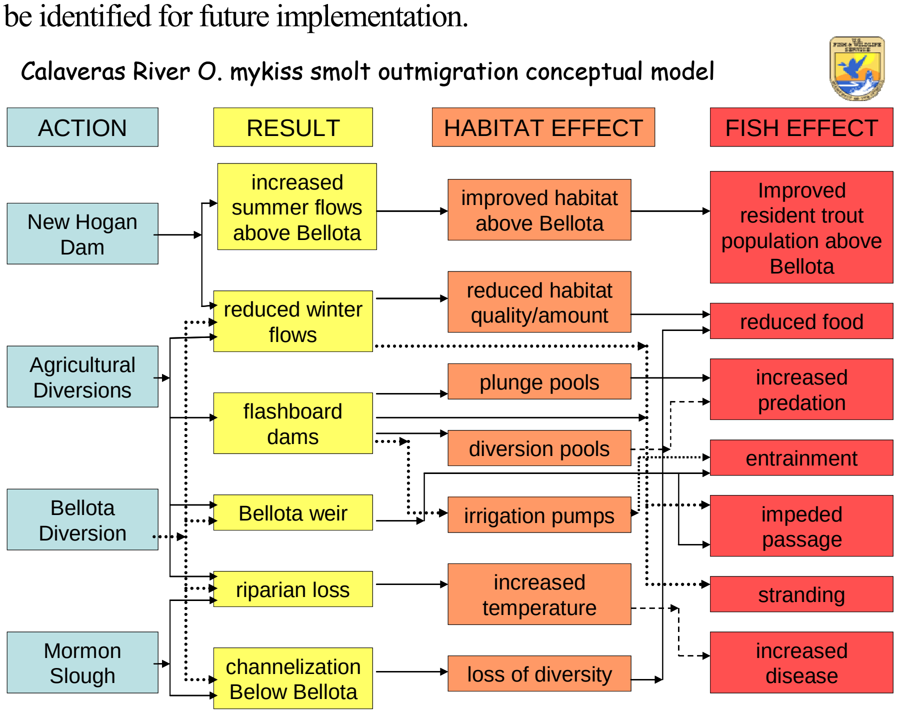

Figure 4. Conceptual model of *O. mykiss* smolt outmigration on the Calaveras River. Prepared by USFWS.

3.3 RESEARCH APPROACH JUSTIFICATION

In developing this study plan, several alternative experimental approaches were considered, including the use of multiple screw trapping locations throughout the basin (including other sampling methods such as seining, fyke netting, and electrofishing), and alternative telemetries such as radio and sonic tracking.

Although two or more rotary screw traps (e.g. upstream and downstream sampling locations) could be operated year-round to provide an index of passage characteristics, screw traps and other sampling techniques can not provide site-specific information for evaluating individual passage barriers and can not provide information regarding numerous other migration characteristics needed to more accurately prioritize restoration actions such as, age distribution during non-peak Summer/Fall migratory period, year-round within stream migratory patterns, daily migration patterns, proportion of fish leaving identified sections of the tributary, travel time through the tributary, and habitat choice in restricted sections of the tributary. Additionally, trapping and other monitoring techniques can not evaluate the fate and behavior of upstream migrating fish, particularly when downstream migration may be impossible for several months during the typical winter outmigration period. Further, there is no location in the lower river where screw traps can be operated below potential passage barriers due to channel morphology and frequency of low flows. During periods of high flows when juvenile data collection is crucial, screw traps can not be operated due to the potential for becoming dislodged from their anchoring system. Therefore, multiple rotary screw trap locations can not be used to evaluate migration issues through the two channels.

Radio and sonic tracking telemetry are inappropriate for this evaluation because both tags require batteries, which increase the size and weight of the tags while also limiting the life-span to a maximum of 1 month, and tags generally run in the neighborhood of $250-300 dollars each. The short duration tag life would prevent adequate evaluation of the multitude of passage issues in the various river reaches and migration channels during different seasons, and the cost of the tags would limit the sample size. Additionally, the significantly larger size and heavier weight of radio and sonic tags would have a greater influence on the behavior and swimming performance of fish than PIT tags, which could lead to incorrect evaluations of passage barriers, where optimal swimming performance is required for the true interpretation of results.

PIT tag technology provides the opportunity to identify the extent of migration delays and the flow conditions necessary for passage at individual structures. Understanding the extent instream structures inhibit migration, both during the irrigation and non-irrigation seasons, will allow us to refine our conceptual model so that restoration actions are focused in areas that are the most important. This knowledge will also increase our ability to conduct beneficial migration route management using natural flows to help maximize juvenile steelhead migration opportunities.

According to Zydlewski et al. (2003), the application of new techniques for remote monitoring of PIT tags (i.e., stationary streamwidth detection arrays and mobile backpack units) not only allows quantification of many typically reported salmonid life history characteristics (i.e., size and age distribution during peak Winter/Spring outmigration period, age at outmigration, parr abundance estimates, outmigration survival estimates, recapture probabilities, and smolt production estimates), but also allows the quantification of some unique characteristics that can not be collected as effectively, or at all, using traditional methods (age distribution during non-peak Summer/Fall migratory period, year-round within stream migratory patterns, daily migration patterns, proportion of fish leaving identified sections of the tributary, travel time through the tributary, habitat choice in restricted sections of the tributary, smolt to adult survival estimates for repeat spawners, kelt migration patterns post-spawning, monitor movement of individual throughout entire life-cycle). Additional benefits of these techniques include only one fish handling event required, continuous remote monitoring of movement past a site, provides a simple method for estimating smolt production that also allows quantification of the numbers of individuals remaining after the peak Winter/Spring migration, and verification of Spring migration patterns and smolt production estimates (Zydlewski et al. 2003). These techniques can provide a "relatively accurate assessment of life history characteristics of steelhead in small streams/tributaries" such as the Calaveras River at reduced efforts (Zydlewski et al. 2003).

4. CAPABILITIES:

The proposed research team consists of a Principal Investigator, two Senior Consultants, a Fish Biologist and several other supporting biologists and technicians. The Principal Investigator will work closely with the Senior Consultants and Fish Biologist to (1) oversee the activities proposed, (2) analyze and interpret results, (3) create a comprehensive report, and (4) present study findings to technical forums. The field work will be conducted by fisheries biologists and technicians.

United States Fish and Wildlife Service (USFWS) Anadromous Fish Restoration Program (AFRP). The USFWS established the AFRP based upon the goal to, "develop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991." From this ambitious foundation, the AFRP has closely worked with federal, private, and local groups to identify issues, find answers, and create solutions. From their efforts, AFRP staff has gained a working knowledge of Central Valley projects, issues, and needs. AFRP participation in research abroad has proven to be integral in successful projects.

J.D. Wikert, Habitat Restoration Coordinator. J.D. Wikert is the Principal Investigator for this Project. He has served as a Habitat Restoration Coordinator for the USFWS for two and a half years after serving 12 years with the Florida Fish & Game Wildlife Conservation Commission. He is assigned to the Calaveras, Stanislaus, and San Joaquin Rivers, and manages the AFRP website. J.D. is knowledgeable about the fisheries issues on the Calaveras River. He facilitates the Calaveras River Fish Group (a technical group focused on anadromous fish issues). He participates as the USFWS representative on the Calaveras River Habitat Conservation Plan work group. He currently manages a project to evaluate the distribution and relationship of resident and anadromous life history of rainbow trout in the Central Valley, a project studying salmonid limiting factors on the Calaveras River, and a rotary screw trapping project on the Stanislaus River.

S.P. Cramer & Associates, Inc. (SPC) was established in 1987 to provide innovative problem solving on issues relating to high-value fish populations in North America. SPC has a team of Senior Fisheries Consultants supported by a team of fisheries biologists and technicians, hydrologists, facility engineers, GIS specialists, and other biological and technical staff. They are known for their scientific approach to determining why fish populations have or may change in response to human actions, and their unique expertise that enables them to find solutions. Their work has been primarily with anadromous and special status fish species on the Pacific Coast and issues that they frequently address include population status and modeling, ESA consultations, habitat condition, watershed restoration, environmental permitting, hatchery assessments, predator management, passage improvements, harvest impacts, and endangered species recovery.

Doug Demko, Senior Consultant. Doug manages and coordinates project activities both within SPC and between cooperating agencies. He also supervises data analyses, interpretation, and report preparation activities. Doug received a Bachelor's degree in Biology in 1992, a Juris Doctor degree in 2002, and has worked in the San Joaquin Basin since 1993. He has led a variety of field sampling projects and has gained the respect of state and federal fisheries biologists as an expert in migrant fish sampling. His experience in the San Joaquin Basin is more extensive than many researchers, and includes project management of studies such as juvenile salmonid outmigration, smolt survival, radio-tracking, predator surveys, resident trout population estimates, habitat surveys, and limiting factors analyses.

Michele Simpson, Senior Consultant. Michele joined SPC in 2002 after working as a fisheries biologist for both the U.S. Bureau of Reclamation and NOAA Fisheries. She received her Master's degree in Biology in 1997. She specializes in Endangered Species Act issues regarding salmonid populations in California including effects analyses of projects potentially effecting listed salmonids including reservoir management, unscreened diversions, fish passage barriers/impediments, and habitat restoration. She also conducts data analyses and report preparation and review of SPC monitoring projects within the Central Valley. In addition, she collaborates extensively with state, federal, and local government agency representatives; landowners, and other interested groups regarding fisheries management issues.

Gabriel Kopp, Fish Biologist. Gabriel joined SPC in 2003 after working with DWR on the Feather River with FERC relicensing. He received his Bachelor's degree in biology in 2003 and is nearing completion of his Master's degree in fisheries. Gabriel has participated in study regarding the feasibility of using passive integrated transponder (PIT) technology in the Calaveras River. He helped plan, design, and implement a field evaluation of a streamwidth detection station similar to the stations proposed in this Project and a laboratory evaluation of surgical tagging methods on *O. mykiss*. Based on this experience, Gabriel is well versed in all required PIT technology methods necessary for implementing the current project plan.

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Appendix A. Technical description and explanation of Passive Integrated Transponder (PIT) technology.

Past Passive Integrated Transponder (PIT) tag research was limited to areas less than 18 inches because researchers were using an alternative PIT system called full duplex. The full duplex system is capable of detecting dense aggregations of fish, but only within confined areas. The system proved beneficial for hatchery flumes or fish ladders, but was limited when applied to natural stream environments. Furthermore, the full duplex system proved temperamental and required significant maintenance to ensure appropriate operation. Researchers needed a different more reliable system capable of larger detection ranges for instream applications.

Due to newer, more reliable half duplex PIT tag interrogation systems, detection ranges can now extend over six feet making this technology an effective means to monitor instream movement of smolt-sized juvenile salmonids. PIT tag interrogation systems are relatively simple and consist of only a few components (i.e., tag, antenna, receiver, datalogger, and powerhouse).

PIT tags are cost effective, small, and light making them an integral tool in fish migration studies. The Calaveras River monitoring program will use the smallest half duplex tag (23 mm in length and 3.85 mm in width; 0.6 g in air) currently available. The tags can be surgically inserted into fish as small as 100 mm. Each tag is a read-only tag that is programmed to transmit a unique code only when activated. Implantable tags are "integrated" circuits with an antenna that are encapsulated in glass. The term "passive" means there is no battery on the tag. The tag is powered through the activation of a field detection station. The tag is uniquely powered by a field detection unit, which is made up of several components working in sync. The detection unit is composed of an antenna, receiver, datalogger, and power source. The detection system works to stimulate metal windings within the tag's ferrite core as the tag enters into a magnetic field generated by the detection station's instream antenna. The energized core bounces a signal back to the antenna. The signal is decoded by a receiver and logged into a Palm datalogger as a unique identification number. With no battery to fail, PIT tags are expected to last 100 years or more (Biomark; located at www.biomark.com). The tag detection and display is almost instantaneous.

The antenna may be constructed in several forms (flow-through, pass-over, wand, or comb) depending upon the physical requirements of the monitoring site. The flow-through antenna design consists of a highly conductive cable that is stretched across the top of the river channel and looped back along the substrate (Figure 1). The pass-over antenna design is laid flat on the substrate in the same rectangular loop as the previous design (Figure 2). The wand antenna consists of a 5 foot wand with an inductor loop approximately 1 foot in diameter attached to the lower end of the wand, similar in appearance to a backpack electrofisher wand. The comb antenna consists of long plastic strips encasing antenna wire held together in a configuration resembling a comb

The monitoring system will incorporate the Texas Instruments PIT tag receiver, TIRFID S-2000 Radio Frequency Identification system. The receiver sends energy through the antenna creating a low-grade electro-magnetic field. The electro-magnetic field is harmless to humans, fish, or any other animals and the energy sent through the antenna will not electrocute even if the antenna were to be lacerated. Similar systems are already in use by the United States Fish and Wildlife Service, Oregon Department of Fish and Game, and California Department of Fish and Game in the Klamath Basin. The field charges the tag as it enters into range. Each charged tag sends back a unique signal, which is identified by the receiver. The receiver interprets the signal and sends it to the datalogger.

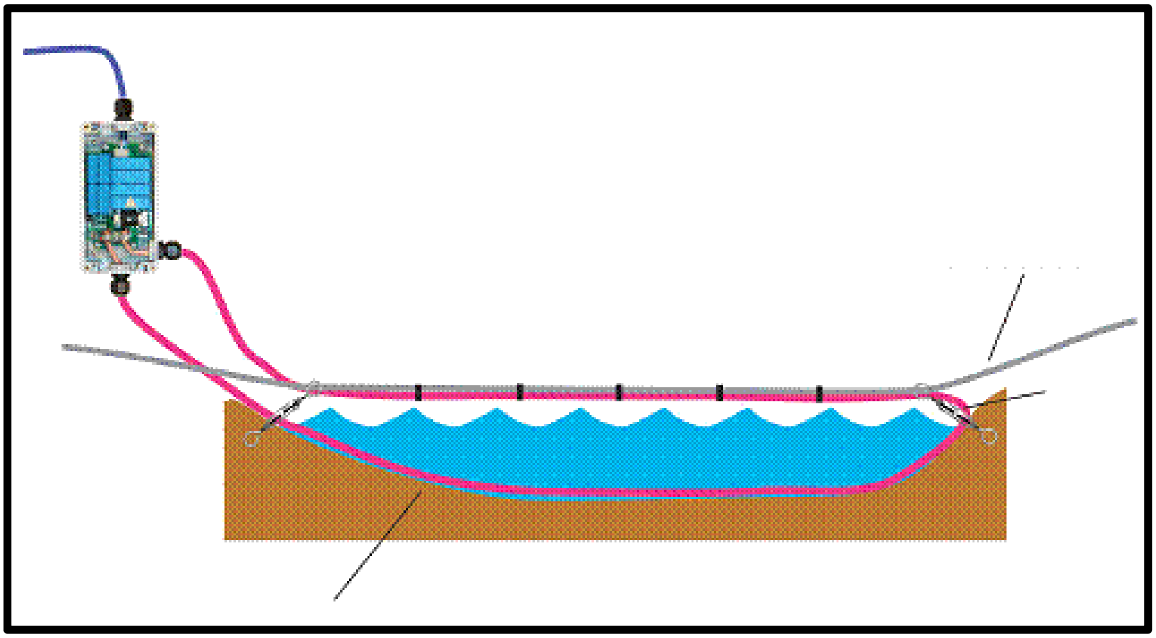

Figure 1. Diagram of a pass-through antenna.

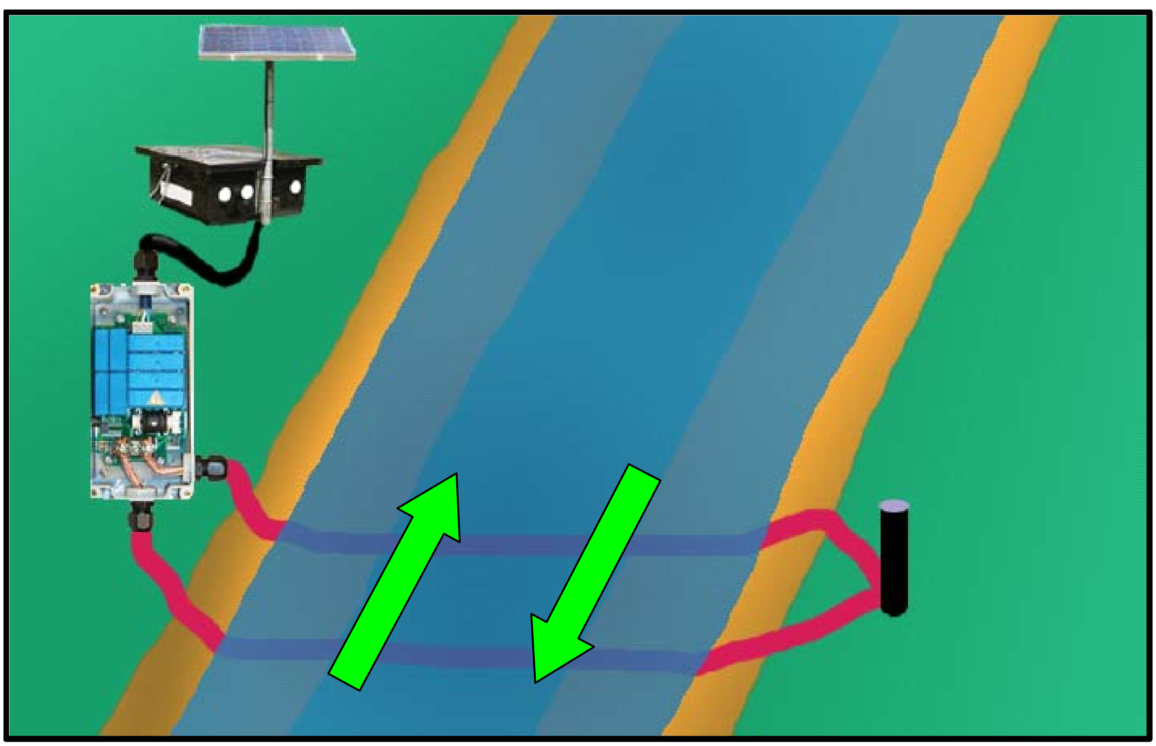

Figure 2. Diagram of a pass-over antenna.

The datalogger takes the code from the receiver and stores it into a memory bank. Past monitoring programs used bulky and expensive notebook computers to datalog. Recent projects have begun using smaller, less expensive Palm computers. New Palm computers are increasingly powerful and the majority of new Palms are sufficient for datalogging. The Calaveras River monitoring project will use an advanced Palm computer capable of remotely sending the information by an internal phone modem to an office database computer. The modem would not only allow for remote monitoring data acquisition, but also allow for the PIT detection station to alert project managers when the antenna is not operating. The modem technology is limited to areas that are capable of maintaining a cellular signal.

For the receiver to send energy through the antenna at the most precise frequency range, a fine tuner is placed between the receiver and the antenna. The receiver is set to operate at a broad frequency range, but the tuner narrows that operating range to optimize the energy being emitted in the electromagnetic field. As the tuning is narrowed into the appropriate frequency, the detection field widens causing for optimal detection ranges. To tune the antenna, a tag is introduced at the outer lateral extent of the detection range. The tuner is adjusted and the transmitter is re-introduced. Adjustments are continually made until it appears that the transmitter is being detected at the furthest extent away from the antenna. Tuning events take two technicians less then one-half hour to complete. After installation, antennas should be tested a minimum of every two weeks to ensure that the antenna remains in tune and is operating at a maximum range.

The power source will be direct ac power when available or solar panels for stationary stations, or battery packs for roving units. Both forms of power source for stationary stations will charge two deep cycle batteries that will serve as an energy store to operate the detection center. Two fully charged batteries will be able to operate for five days if power is temporarily lost. Solar energy has been used in past projects by SPC, including the Stanislaus River Vaki Camera system. SPC has found the solar powered system to be efficient and dependable.

For stationary detection stations (fixed and mobile), a receiver, tuner, datalogger, and battery pack will be housed on land in a metal lock box located outside the bankfull channel to avoid submerging the enclosure. The lock box will be secured to a concrete slab for additional protection against weathering and vandalism. Two types of antennae (flow-through or pass-over) may be used depending on the location and both types will be supported by aircraft cable and enclosed in thick exterior rubber tubing to protect from high flow events or vandalism. The flow-through design has an effective lateral scan area of ≥6 ft and a depth range of 5-6 feet. While the flow-through configuration has higher detection ranges, if it is placed in open stream areas the antenna is either exposed above the water or slightly below the water's surface. This may pose a mild hazard or annoyance to recreational users, so this configuration style will only be attached to existing instream structures, such as culverts or flashboard dams. The pass-over design has an effective lateral and depth scan area of ~3-4 ft. Although the detection range for this antenna is lower, this antenna configuration is the preferred methodology in open water areas because the antenna is not exposed.

Two types of roving stations will be constructed: a backpack detection system and a trawl detection system. The backpack detection system design will resemble a previously designed unit employed on Abernathy Creek and looks similar in appearance to a backpack electrofisher ((Zydlewski, et al. 2002)). A receiver, tuner, datalogger, and battery pack will be enclosed in the detection system housing and secured to an aluminum frame backpack. A wand antenna will be used to sweep through the stream actively searching out tagged fish. This backpack system has shown past detection efficiencies ranging from 33% to 65% (Zydlewski et al. 2002). While detection efficiency is not as high as stationary streamwidth monitoring systems, the data collected by the roving unit will cost effectively expand monitoring area, help locate undetected fish, and allow for exact location data to be taken to assess microhabitat use. A trawl detection system will be mounted to a kayak and maneuvered within the stream channel to survey deeper more challenging reaches. A receiver, tuner, datalogger, and battery pack will be enclosed in waterproof housing on the kayak. A comb antenna will be mounted on the back of the kayak. The pliable plastic comb antenna will be towed through the stream channel allowing for fish to pass by and be detected. Other trawling PIT detection systems have been used on the Columbia River and shown successful results with detection ranging from 41-83% (Ledgerwood et al. 2004). The trawl detection system will allow for efficient active monitoring of areas that could not otherwise be evaluated by the roving backpack detection system.

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